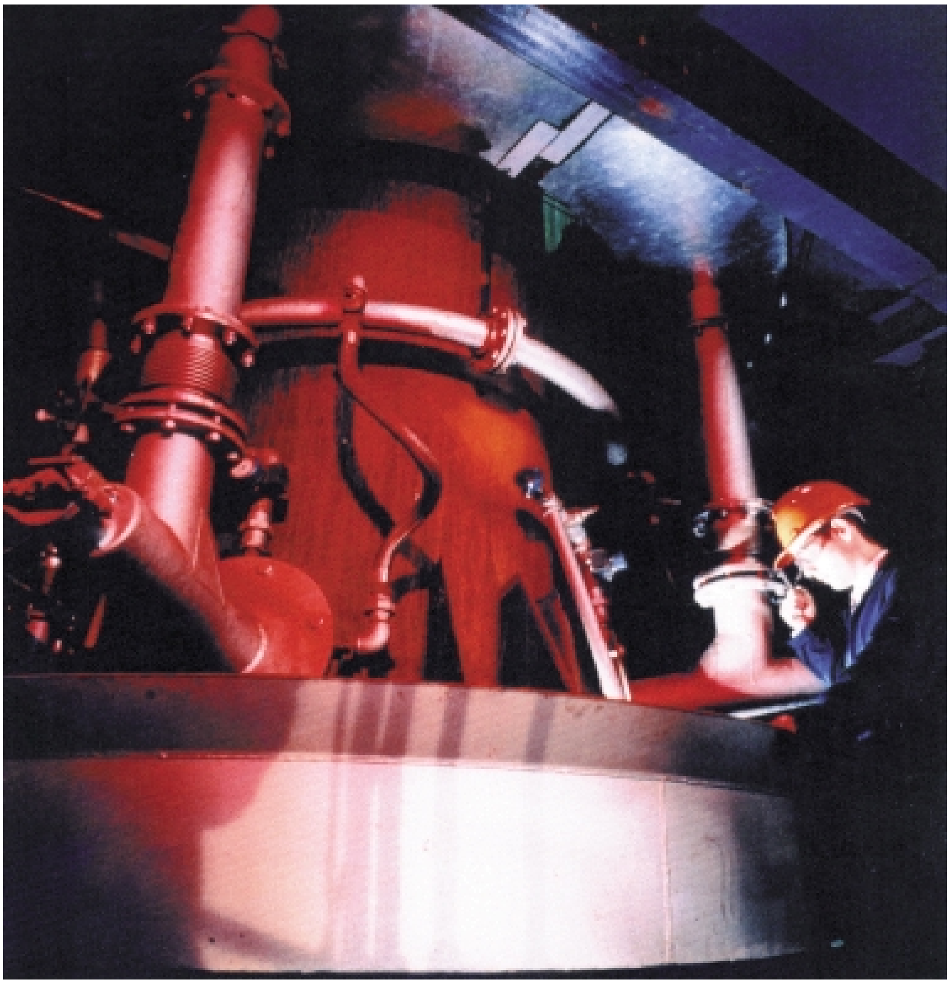
DETR
Environment
Transport
Regions

GOOD PRACTICE CASE STUDY 366

Long campaign hot-blast cupolas in iron foundries

Sinclair Foundry Products



- Total investment of £1.8 million
- Very large coke and metal cost savings
- Good payback on marginal investment cost
- Particulate emissions of less than 5 mg/m^3

GOOD PRACTICE CASE STUDY 366

BEST PRACTICE PROGRAMME
ENERGY EFFICIENCY

BEST PRACTICE PROGRAMME

HOST ORGANISATION

The cost of melting iron in any foundry forms a significant part of the overall manufacturing costs. The ability to melt a wide range of ferrous materials with an energy efficient installation is fundamental to the future success of this business. The selection of a new melting facility is a 'one off' decision that remains with the business for decades to come; therefore the selection has to be a 'right first time' decision.

The long campaign hot-blast cupola has proven to be an excellent decision for this business in terms of energy efficiency and flexibility. The initial justification criteria of coke savings, ferrous material flexibility and environmental compliance have all been satisfied. The reduction on metal and melting costs will give a payback within six years on the total capital spend, in line with the original justification. Payback can be reduced significantly if expressed using a marginal approach - for example, if the cost of upgrading equipment or the savings associated with increased metal demand are taken into account.

Without doubt this project has proven to be a very successful one with all criteria satisfied, and a good basis for the business to go forward for the future.

Mr G A O'Brien
Manufacturing Director, Sinclair Foundry Products

SINCLAIR FOUNDRY PRODUCTS

Continuous production of cast iron products has taken place at the Sinclair Works since the start of the twentieth century. Located on a 54-acre site in Telford, Shropshire, the Sinclair Works melts 25,000 tonnes of cast iron annually for the production of drainage castings and water pipes and fittings, 80% of which are sold directly. The company employs 380 people at this site.

Note: Prior to a company takeover, Sinclair Foundry Products was known as Glynwed Foundries.

BACKGROUND

BACKGROUND

Most cupola melting plant is based on cold-blast cupolas. Although many foundries have modified their operations to include such improvements as divided blast operation, the use of automatic blast control, oxygen enrichment and better charge weighing practices, the basic procedures have changed little over many decades.

Until recently, hot-blast cupolas were economical only for UK foundries with large continuous requirements for molten iron. It was known that these units offered good energy efficiencies and low operating costs. However, hot-blast units fell under the control of the Alkali Inspectorate and had to comply with a stringent emission limit of 115 mg/m^3; this meant they had to be fitted with high efficiency filtration equipment. Since the same limits were not imposed on cold-blast units, the capital costs associated with hot-blast units were prohibitively high for all but the largest operators.

With the advent of statutory requirements under the Environmental Protection Act (EPA) 1990, all future cupola melting installations, irrespective of the melting technique employed, will need to be equipped with high efficiency filtration systems. Thus, the cost premium previously associated with hot-blast units has been lost and the economic justification for hot-blast units can be extended to smaller installations.

Most hot-blast cupolas are operated on long campaigns, many with unlined shells in the melting zone which are externally water-cooled. Both independently fired and recuperative hot-blast systems have been used; however, the high fuel cost and poor performance of independent units have resulted in the abandonment of most of these systems. Recuperative hot-blast systems, incorporating combustion of the cupola offtake gases, are the most common hot-blast arrangement.

There is an emerging trend for hot-blast cupolas to be operated for long shift periods or extended campaigns. This overcomes the lower thermal efficiency of cold-blast furnaces where considerable heat loss to the cooling water arises, leading to higher coke utilisation in an effort to maintain adequate metal temperatures.

Owing to the need to combust gases prior to filtration and the tendency to adopt changes in operating practices, such as extended melting periods and long campaign cupola operation, there is renewed interest in the hot-blast cupola in the UK.

The savings in both energy consumption and operating costs by replication within the iron-founding industry are potentially large. In order to demonstrate the cost-effectiveness of this type of melting operation, an Energy Efficiency Best Practice Programme Case Study has been undertaken on the FTL/Wrib cupola installed in 1995 at the Sinclair Works foundry in Telford.

The project was monitored independently by: The Castings Development Centre. Tel: 01527 66414.

Equipment supplied by: Foundry & Technical Liaison Ltd. Tel: 01902 630222.

There may be other suppliers of similar energy efficient equipment in the market. Please consult your supply directories or contact ETSU who may be able to provide you with more details on request.

ADVANTAGES OF THE HOT-BLAST CUPOLA MELTING OPERATION

ADVANTAGES OF THE HOT-BLAST CUPOLA MELTING OPERATION

Hot-blast operation involves preheating the cupola blast air in the region of 500°C. This promotes a faster reaction between oxygen in the blast air and the charge coke, and reduces the chilling effect of the incoming air in the melting process. Compared with cold-blast cupolas, the consequent advantages of hot-blast operation, in terms of cupola performance, may be summarised as follows:

- reduced coke consumption;
- increased metal temperature;
- higher melting rate;
- reduced sulphur pick-up;
- lower melting losses;
- increased carbon pick-up.

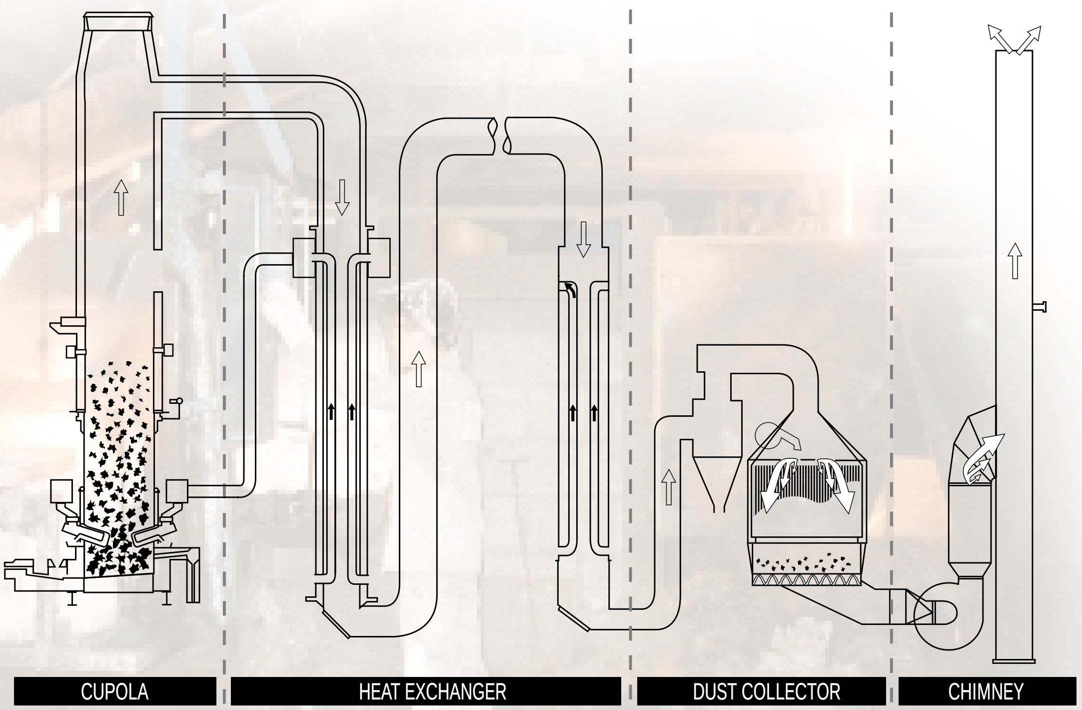
However, it should be noted that not all of these benefits may be attainable simultaneously.

While the hot-blast cupola will always be better suited to volume metal production, advances in technology are extending its economic range down to minimum melting rates of 6 tonnes per hour. This compares with 10 tonnes per hour, commonly accepted as the 'minimum' size in the UK a few years ago when the legislation on emissions from hot-blast units was more stringent than that for cold-blast operations.

JUSTIFICATION FOR CHANGE

Originally the Sinclair Works foundry employed six pairs of cold-blast cupolas to supply iron to its pipe-spinning and gutter plants, and its Disamatic and special products operations. Because the company was faced with a need to rationalise its melting operations, and at the same time required to comply with the EPA (1990) legislation regarding particulate emissions, a decision was made to 'upgrade' the cupolas supplying metal to the pipe-spinning plants and special products section, by October 1995. As a consequence, a 'Plan for Change' was developed which involved a comprehensive review of all melting options. The main criteria for selection of a new melting facility were to:

- comply with the statutory requirements of the EPA (1990) and Control of Substances Hazardous to Health (COSHH) regulations;
- increase melting capacity to satisfy existing and future demand;
- provide energy savings to remain competitive;
- be capable of utilising a wide range of metallic charge materials;
- allow flexibility in melting rate;
- consistently produce iron of correct chemical composition and temperature;
- employ only proven technology.



CHOICE OF MELTING PLANT

CHOICE OF MELTING PLANT

As a result of the review, the company decided to install an externally cooled, unlined, long campaign cupola providing a melting rate capability of between 8 and 12 tonnes per hour, to supply molten iron to its four production areas. In making this decision certain other requirements were stipulated:

- a metal temperature of 1,520°C leaving the siphon box;
- a maximum coke charge of 10%;
- particulate emissions of less than 20 mg/m^3;
- no interruption to manufacture during installation.

The cupola (shown schematically in Fig 1) is fitted with four, protruding, Wrib, copper spiral-sheathed tuyères which are water-cooled. Combustion of the offtake gases is maintained by a combination of an annular air-mixing ring located below the charge door and an after-burner which automatically ignites if the temperature of the rising gases falls below a pre-set level. The offtake gases are drawn from the cupola through an Escher recuperator, which effectively preheats the incoming blast air to between 490 - 500°C, this being subsequently enriched with 1.5 - 2.0% oxygen. The waste gases are then cooled to approximately 175°C, after which they pass through a dry bag filter unit prior to discharge to atmosphere via a 25 m-high stack.

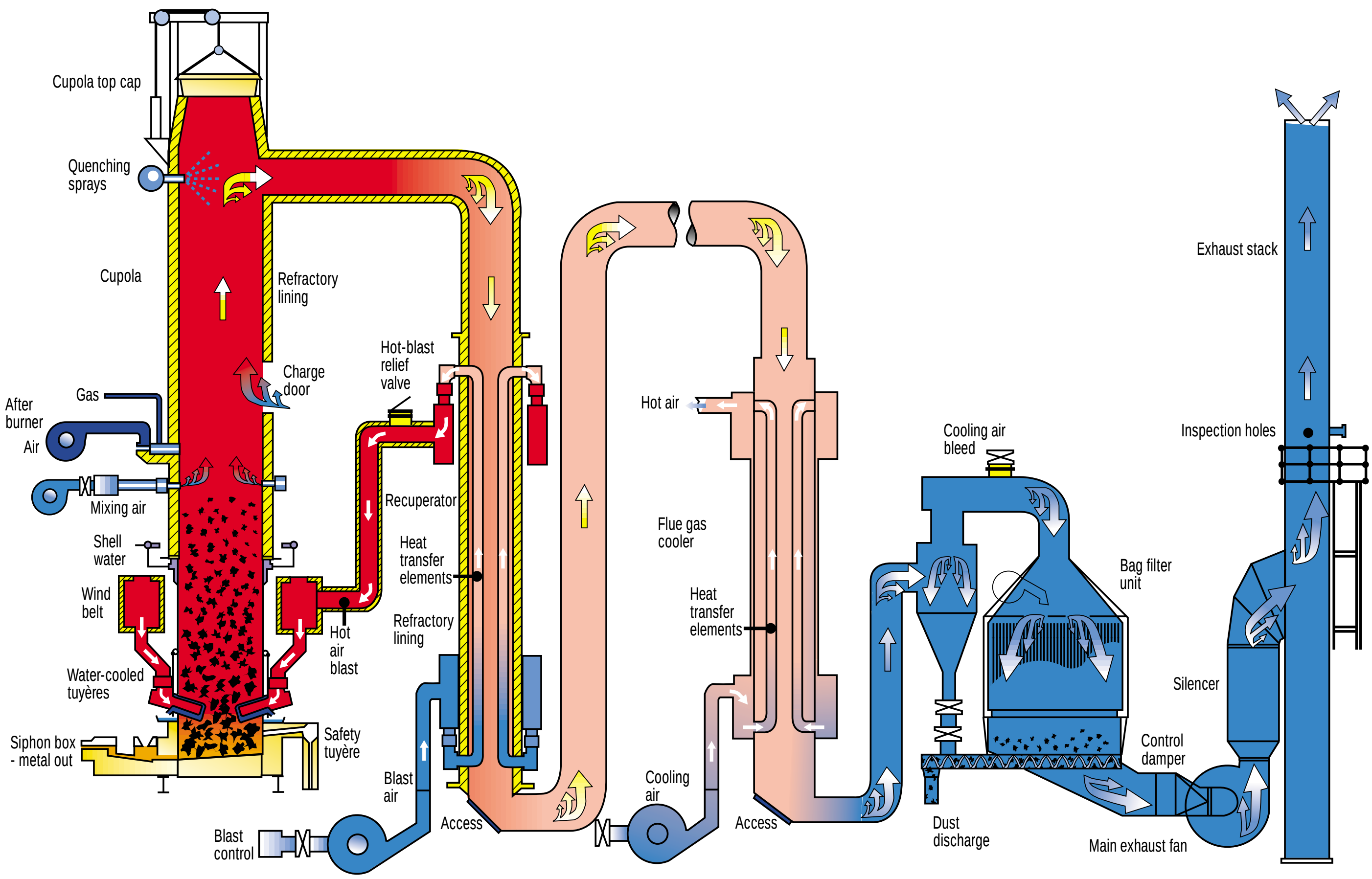
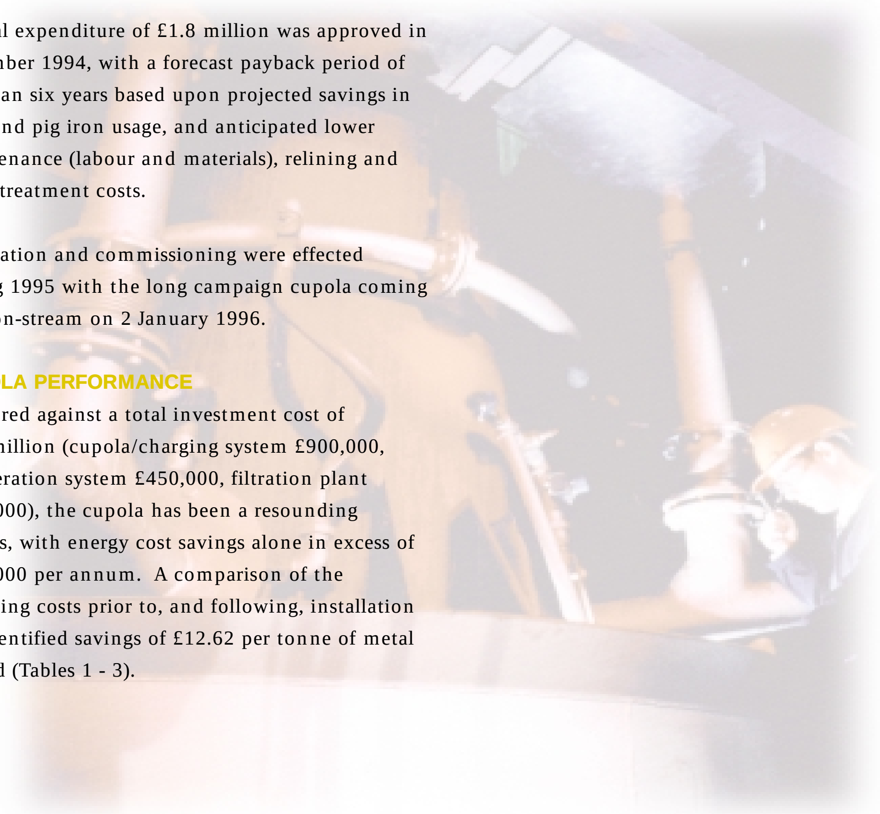


Fig 1 Schematic diagram of the FTL/Wrib long campaign cupola

CUPOLA PERFORMANCE



Capital expenditure of £1.8 million was approved in December 1994, with a forecast payback period of less than six years based upon projected savings in coke and pig iron usage, and anticipated lower maintenance (labour and materials), relining and water treatment costs.

Installation and commissioning were effected during 1995 with the long campaign cupola coming fully on-stream on 2 January 1996.

CUPOLA PERFORMANCE

Measured against a total investment cost of £1.8 million (cupola/charging system £900,000, recuperation system £450,000, filtration plant £450,000), the cupola has been a resounding success, with energy cost savings alone in excess of £200,000 per annum. A comparison of the operating costs prior to, and following, installation has identified savings of £12.62 per tonne of metal melted (Tables 1 - 3).

Table 1 Charge costs: before and after installation

Material	Cost* (£/t)	1995 Cold-blast operation		1996 Hot-blast operation	
		Addition (%)	Cost (£/t)	Addition (%)	Cost (£/t)
Pig iron	130.03	14.46	18.80	4.90	6.37
Bought scrap	84.83	65.36	55.44	71.80	60.91
Steel scrap	82.06	-	-	5.19	4.26
Return scrap	84.71	18.94	16.04	16.80	14.23
Ferro-silicon	656.12	0.92	6.04	1.07	7.02
Ferro-manganese	469.92	0.11	0.52	0.08	0.38
Inoculant	1116.50	0.21	2.34	0.16	1.79
Total		100.00	**99.18**	100.00	**94.96**

** Costs reflect average raw material price for 1996. The 1995 prices have been adjusted to the 1996 equivalent in order to make a meaningful comparison.*

CUPOLA PERFORMANCE

Table 2 Melting costs: before and after installation

	1995 Cold-blast operation Cost* (£/t)	1996 Hot-blast operation Cost* (£/t)
Energy		
Bed coke	2.15	2.24
Charge coke	23.17	14.96
Oxygen	3.26	1.97
Electricity	1.12	1.29
Gas	0.04	0.78
	29.74	21.24
Refractories		
Ganister/gunning	2.15	0.08
Consumables		
Limestone	0.49	0.26
Maintenance	3.22	3.30
Others	3.59	4.46
	7.30	8.02
Labour		
Direct/indirect/maintenance	12.90	14.35
Total	**52.09**	**43.69**

* *Costs reflect averages for 1996. The 1995 prices have been adjusted to the 1996 equivalent in order to make a meaningful comparison.*

Table 3 Total operating costs: before and after installation

	Operating costs (£/t)	
	1995 Cold-blast operation	1996 Hot-blast operation
Charge costs	99.18	94.96
Melting costs	52.09	43.69
Total operating costs*	151.27	138.65
Savings per tonne of iron produced**	-	12.62

* *Excluding plant hire, depreciation, yard/general services, rates/rents and insurance.*

** *Compared with cold-blast operation.*

CUPOLA PERFORMANCE

Thus, working on metal production of 25,000 tonnes per annum, total operating savings work out at £315,000, of which over £200,000 are savings in the melting costs. When combined with anticipated lower maintenance (labour and materials), relining and water treatment costs, the annual total saving to the company was £436,000, equivalent to £17.44 per tonne of metal melted.

A more effective comparison may be obtained if the effect of true yield is taken into account, i.e. the ratio of the weight of castings sold to the amount of raw materials charged. For example, to produce one tonne of castings with a true yield of 75%, it would be necessary to melt 1.33 tonnes of iron. Not all of this additional metal would be recycled in view of the non-recoverable losses (typically 5%) which inevitably occur in cupola melting and metal handling, namely in the form of dross, spillage and evaporation. This material can then be returned for remelting at a proportion of the average charge cost. Using this approach, Table 4 shows the comparison, based on yield, between the cold and hot-blast operations, indicating an overall saving of £17.40 per tonne of good castings produced following installation of the new plant.

Table 4 Economic comparison: before and after installation - based on yield

	1995 Cold-blast operation		1996 Hot-blast operation	
		Cost (£/t)		Cost (£/t)
Cost per tonne of metal melted (excluding yield)		151.27		138.65
Cost per tonne of metal melted (including yield)	@ 74.7% true yield	202.50	@ 76.9% true yield	180.30
Less recovered value of foundry returns	339 kg @ £99.18/t = £33.62 - 5.2% metal loss = £1.75	31.87	300 kg @ £94.96/t = £28.49 - 5.0% metal loss = £1.42	27.07
Melting costs to produce one tonne of good castings	£202.50 - £31.87	170.63	£180.30 - 27.07	153.23

CUPOLA PERFORMANCE

Iron being taken from the cupola to the pipe-spinning plant

Cost savings of £17.44 per tonne of metal melted during the first quarter of 1997 are in close agreement with the company's initial projection of £16.90 per tonne. This reduction has resulted from a combination of the large energy savings, plus an average 13% reduction in the cost of metallic charge materials during this period.

An indication of the principal changes in operating characteristics are shown in Table 5.

Table 5 Changes in operating characteristics: before and after installation

	Cold-blast (%)	Hot-blast (%)
Bed coke	1.46	1.59
Charge coke	15.61	10.57
Pig iron	14.46	4.90
Gas consumption	-	0.78

CUPOLA PERFORMANCE

The main sources of savings can be found in the reduced coke consumption and markedly lower usage of pig iron in the charge. It is anticipated that additional savings will be achieved once the present reduced demand for molten iron recovers. The study has clearly shown that total production costs have reduced as familiarisation in operating the plant has been gained; this was maintained during 1997 despite increased melting costs due to higher than anticipated maintenance costs resulting from specific problems with the copper tuyères. It is expected that these problems will be resolved shortly, providing even greater economies.

The flexibility of the new plant has been clearly demonstrated by its ability to produce molten iron at a reduced melt rate of 6 tonnes per hour and also on occasions when operating with only three tuyères.

Current operating practice is to work a minimum of four, 20-hour melting periods each week, each divided into two 10-hour shifts. The longest campaign operated to date is seven weeks, the aim being ten weeks before dropping the bottom.

The environmental effectiveness of the operation can be measured by the fact that particulate emissions are now less than 5 mg/m^3 compared to the limit of 20 mg/m^3 demanded in the 1996 Process Guidance Regulations (PG 2/5 (96)).

The dust collector and chimney at Sinclair Foundry Products

PEOPLE ISSUES

PEOPLE ISSUES

It is now generally accepted that the effective management of change can be achieved only through a well-informed, supportive workforce. The considerable emphasis that has been placed upon this issue by senior management was very apparent from the study. The approach to teamworking, team selection and training could, in itself, be adopted by the industry as a benchmark, thereby creating a much needed impetus for others to act accordingly and increase competitive advantage. The success of the new, long campaign, hot-blast cupola at the Sinclair Works has ultimately been enhanced by its well-trained, motivated staff.

ECONOMICS

A very simple payback calculation, based on the information provided within this Case Study, is 4.1 years. This assumes:

- a total investment cost of £1.8 million;
- 'typical' 1997 raw material prices;
- estimated total annual savings of £436,000;
- a metal demand of 25,000 tonnes per annum.

However, accepting that the company would have to significantly upgrade the dust arrestment capabilities on its existing cold-blast cupolas in order to comply with the requirements of EPA (1990) by 1997, it is more realistic to express payback on a marginal approach. Therefore, excluding the cost of the dry bag filtration equipment (£450,000), the payback period would be reduced to 3.1 years, even if metal demand were to remain at its relatively low level.

Very large additional savings would be made with increased metal demand. Increasing the tonnage of metal melted by 10,000 to 35,000 tonnes per annum (achieved by melting at 9 tonnes per hour ‘around the clock’ for 3 - 4 days a week) would result in additional benefits worth £165,000 per annum. These will be through a combination of economies of scale (melting additional metal in the efficient unit), saving £12.34 of energy and metal per tonne, plus savings in bed coke (estimated to be worth £1.17 per additional tonne of metal for the entire production). For a total of 35,000 tonnes per annum, total savings of £601,000 per annum would be realised, which would further reduce the payback period to 2.25 years.

Finally, if a foundry that needed to rebuild its existing cold-blast cupola were to consider converting to hot-blast, then part of the cost of the rebuild should be discounted from the analysis. In effect, the foundry manager should consider payback only on the additional costs that are incurred over what is absolutely necessary, which are:

(a) the 'premium' of specifying a hot-blast melt unit over a standard cold-blast unit; plus

(b) the 'recuperation system', i.e. the heat exchanger unit.

ECONOMICS

It was not possible to do a direct comparison for Sinclair Foundry Products, because the new hot-blast cupola replaced a number of existing melt units. However, it is not unreasonable to assume a 10 tonnes per hour cold-blast unit would be approximately half the cost of an equivalent hot-blast unit, i.e. £450,000. Thus, the 'premium' for hot blast is only £450,000. It is clear that, with this analysis, the payback period on marginal additional investment is reduced significantly - to 18 months.

The above calculations are summarised in Table 6.

At Sinclair Foundry Products, other environmental cost-saving opportunities are also being investigated. These include 'through tuyère dust injection' to convert dust - which would otherwise have gone to landfill - to produce increased volumes of slag, for which beneficial re-use opportunities have been identified.

It is worth noting that payback is not necessarily the best way to evaluate larger capital investments. 'Net present value' or 'internal rate of return' should provide a fairer assessment, particularly if the unit has a planned life of several years. It is advisable to explore these financial methodologies before accepting or rejecting hot-blast cupolas.

Table 6 Payback calculations for different analyses

	Investment (£ 000's)	Saving (£ 000's per year)	Payback (years)
Payback on full investment	1,800	436	4.13
Discount dust arrestment unit	1,350	436	3.10
Extra throughput, reduced bed coke	1,350	601	2.25
Discount cold-blast unit cost	900	601	1.50

The Department of the Environment, Transport and the Regions' Energy Efficiency Best Practice Programme provides impartial, authoritative information on energy efficiency techniques and technologies in industry, transport and buildings. The information is disseminated through publications, videos and software, together with seminars, workshops and other events. Publications within the Best Practice Programme are shown opposite.

Further information

For buildings-related topics please contact:
Enquiries Bureau
BRECSU
Building Research Establishment
Garston, Watford, WD2 7JR
Tel 01923 664258
Fax 01923 664787
E-mail brecsuenq@bre.co.uk

For industrial and transport topics please contact:
Energy Efficiency Enquiries Bureau
ETSU
Harwell, Didcot, Oxfordshire,
OX11 0RA
Tel 01235 436747
Fax 01235 433066
E-mail etsuenq@aeat.co.uk

Energy Consumption Guides: compare energy use in specific processes, operations, plant and building types.

Good Practice: promotes proven energy efficient techniques through Guides and Case Studies.

New Practice: monitors first commercial applications of new energy efficiency measures.

Future Practice: reports on joint R & D ventures into new energy efficiency measures.

General Information: describes concepts and approaches yet to be fully established as good practice.

Fuel Efficiency Booklets: give detailed information on specific technologies and techniques.

Energy Efficiency in Buildings: helps new energy managers understand the use and costs of heating, lighting etc.